TECHNICAL INFORMATION ON BUILDING MATERIALS

TIBM - 26

FOR USE IN THE DESIGN OF LOW-COST HOUSING

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WALL PLASTER, MIXING, AND APPLICATION

This is the second in a series of three sections of a digest of Circular C151, "Wall Plaster: Its Ingredients, Preparation and Properties", (January 9, 1924),[1] issued by the Bureau of Standards. This section deals with ingredients and application.

Materials

The properties of any plastering material should be considered from the following standpoints in order to determine its value. When in the plastic state, can it be spread into position without requiring an impractical amount of care and effort? Does it harden quickly enough to prevent undue delay in the building operation and is the shrinkage, which normally accompanies the hardening, negligible? How closely do the properties of the hardened material approach the desired standards?

All plasters must contain at least one cementitious material, generally lime, gypsum, or portland cement. Sand is used to increase capacity and to reduce shrinkage. Water is necessary to develop the plasticity of the cementitious material, and to assist in the chemical reactions involved in the hardening process.

Lime: Quicklime is made by heating limestone to a temperature of over 900°C. It consists essentially of calcium oxide or of calcium and magnesium oxides. Lump lime will deteriorate when exposed to air and, therefore, must be kept in air and moisture-proof containers, or slaked immediately upon receipt.

When water is added to quicklime, a chemical reaction takes place. The calcium oxide is converted to calcium hydroxide, and the

[1] Available from Superintendent of Documents, Washington, D. C. (Price 10 cents).

magnesium oxide may or may not be converted into magnesium hydroxide, depending upon how hard it was burned. This reaction is known as slaking. If an excess of water is used, lime putty results. In this form, lime may be stored indefinitely, provided only that it is protected against drying out. The value of the quicklime depends very largely upon its being properly slaked, different kinds of lime requiring radically different treatments to obtain the best results.

Hydrated lime is made from quicklime by slaking it with just enough water to complete the chemical reaction. It comes in the form of dry, white powder, and is sold in paper bags containing fifty pounds each.

Lime putty is made from hydrated lime by adding water. When exposed to the air, it loses water by evaporation, causing a decided decrease in volume. It then combines with the carbon dioxide of the air, which unites with both the calcium and magnesium to form the respective carbonates. Upon the interlocking of these carbonate crystals depends the strength of the hardened material. A peculiarity of this reaction is that it will not occur unless there is a small amount of water present. In other words, lime plaster will not harden properly under exceedingly dry conditions. Neither will it harden successfully when excessively and continuously damp.

Both quicklimes and hydrates are divided commercially into two grades on the basis of plasticity--masons' and finishing. Only plastic limes should be used in the finish coat of plaster.

Gypsum: Gypsum is a native rock, composed essentially of calcium sulphate, crystallized with about 20 percent of water. When heated to about 110°C, three-fourths of the water content is driven off producing that product known as "stucco" at the mill; "plaster of Paris" by the trade; and according to the most modern designation "calcined gypsum".

When water is added to calcined gypsum, the solid material dissolves and crystallizes in the form of the original gypsum, using some of the water in the process. The strength of the set material depends upon the effectual interlocking of these crystals of gypsum.

The comparatively great solubility of calcined gypsum in water accelerates the hardening reaction which usually requires about ten minutes. One of the most important properties of gypsum is that the time of set may be controlled by the use of accelerators and retarders. For the purpose of retarding the time of set, an organic compound similar to glue is sold under the trade name of "commercial retarder". One-fourth of one percent of this material added to calcined gypsum is enough to retard the hardening for about two hours. If this is not available, ordinary glue will give the same results.

Gypsum neat plaster may be produced by adding to calcined gypsum about one-sixth of its weight of hydrated lime and enough retarder to

make it set in about two hours. This is the chief gypsum product used by the plastering trade. It may be had either fibered or plain and is sold in bags containing one hundred pounds each. Gypsum ready-sanded plasters contain all the necessary ingredients, except water, for either scratch coat or brown coat work. Sometimes a shredded wood fiber is used instead of sand, the product being designated gypsum wood-fibered plaster.

Portland Cement: Portland cement is made by heating a natural or artificial mixture of limestone and clay to above 1,200° C, or until it begins to melt. The partially vitrified material is then ground to a fine powder and mixed with a small amount of gypsum to retard its set. It is shipped in cloth or paper bags, containing ninety-four pounds each.

Portland cement requires water in its hardening process and for complete hydration a sufficient supply of water must be maintained for many days. The conditions to which wall plaster is ordinarily subjected are not those best adapted to developing the full strength of portland cement. On the other hand, portland cement is peculiarly adapted for use as a plaster under continuously and excessively damp conditions.

Since one of the products of the hydration of portland cement is hydrated lime, the hardened material will have an alkaline nature.

Keene's Cement: Keene's cement is made from gypsum heated to such a temperature that its water content is driven off. This product when mixed with water will re-crystallize, developing hardness. The reaction takes place so slowly, however, that a small amount of some chemical, such as alum, is used to accelerate its hardening. Keene's cement is used for plasters requiring a hard, smooth surface.

Sand: Care should be exercised in the selection of sand, the principal aggregate in plaster. Both the angular and globular types are satisfactory and may be either natural sand or ground rock. It should be composed of clean, hard, durable stone particles, free from objectionable matter, with an allowance of not more than 5 percent of loam, silt and clay. Sand for plaster should be graded to pass a No. 3 or No. 4 sieve and at least 85 percent should be retained on a No. 100 sieve.

Fiber: The only function of fiber is to enable the plaster to be spread in place without losing too much of it through "dropping". The fiber may be of animal or vegetable origin and should be long enough to serve its purpose (one-half inch), but not so long that it will tangle (2 inches). It should be flexible enough to stay buried in the plaster, and should be clean, for dust in the fiber is as objectionable as dust is in the sand. It should be evenly distributed throughout the plaster.

Water: Sea water, or water known as brackish, sulphur, chalybeate or carbonated, should not be used for plastering. With the

above exceptions, ordinary drinking water should prove satisfactory.

Ready-mixed Plaster: Ready-mixed plasters may be obtained, manufactured from either gypsum or lime and containing all the ingredients, except water, necessary for either scratch or brown coat. Where delivery cost is not excessive, they offer many advantages. Mixed by machinery under expert supervision, they are more nearly uniform and homogeneous than plasters mixed by hand at the work. The great drawback being cost of transportation, if a reasonably good sand can be had locally, it is poor economy to pay freight on a ready-mixed plaster.

Ready-mixed Mortar: Ready-mixed lime plaster to which water has been added is now available in some cities. It is sold as "ready-mixed mortar" and is equally serviceable as mortar, plaster, or stucco. Where available, it has many advantages. The architect and contractor are relieved from all responsibility in regard to the purchase, storing, proportioning, and mixing of the various ingredients. The lime putty is more thoroughly aged, and the mixing is more uniform than could be accomplished by hand. Its value is finally determined by whether or not the delivered cost is lower than the cost of buying the ingredients and mixing them on the job.

Properties of the Wet Mix

Plasticity: The plasticity of the wet mix is determined by the physico-chemical properties of the cementitious material used. A finishing hydrate has considerably more plasticity than a mason's hydrate. Consequently, its commercial advantages are apparent, as the more plastic a plaster, the easier its application.

Shrinkage and Sand Carrying Capacity: While sand reduces shrinkage in plaster, it also decreases the strength of the material. Therefore, its proportion should be commensurate with the purpose of the plaster. Oversanding of plaster should be avoided as such plaster lacks strength (See Page 6 "Proportions"). The more plastic a material, the greater its sand-carrying capacity, as far as workability is concerned. A certain amount of sand may be added to a cementitious material without seriously affecting its working quality, while a small additional quantity of sand may change the character of the mixture from that of cementitious material to sand.

Time of Set: The time of set of a plaster has a bearing on the cost of a finished wall. Quick-setting plaster should be mixed in such quantities as can be applied without loss of material. By the use of accelerators and retarders the time of set of gypsum plaster may be regulated.

Mixing and Application

Storage: All cementitious materials should be kept dry until used.

Weather Conditions: For plastering the ideal atmospheric condition is warm and humid. Plaster should not be applied to a masonry wall containing frost, nor under such conditions that the plaster may freeze before it has a chance to harden. Very damp and cool conditions may interfere, but will not permanently affect the hardening of lime and gypsum unless these conditions persist. The rapid evaporation of water may cause excessive shrinkage. It is possible that enough moisture may be lost in this way to prevent the hardening reaction.

Mixing: When the ingredients of plaster do not require preliminary soaking, the dry materials should be mixed thoroughly to a uniform color. They should then be added to the water (water should not be added to the dry materials unless a mixing machine is used) and mixed thoroughly to a uniform consistency. As little water as possible should be used to bring the plaster to such consistency that it may be properly worked. Excess water may cause trouble, due to segregation, difficulty of application, loss of material as droppings, or excessive shrinkage.

Sometimes one of the ingredients must be soaked before using, as in the case of quicklime, or in order to develop the full plasticity of a finishing hydrate.

Grounds: Ground strips are narrow strips of wood or metal placed around and parallel to the edges of the surface to be plastered and all openings therein, and are attached to the backing. They were originally designed to be used as guides for a straightedge, to bring the brown coat to a true and even surface. The thickness of these ground strips should, therefore, govern the thickness of the plaster. Spot grounds are also sometimes used, being pieces of wood attached to the backing at various intervals.

Functions of the Different Coats: Plaster is applied in not more than three coats, designated in order of application as "scratch", "brown", and "finish". The primary function of the first or scratch coat is to act as a bond, attaching the body of the plaster to the base. It should have plasticity, cohesion, and strength when set.

The brown coat forms the main body of the plaster. Quick hardening is not so necessary as for the scratch coat, it being customary to allow ample time for this coat to dry completely before the finish coat is applied. It is important, however, that the brown coat have sufficient hardness to provide a good backing for the finish coat, so that in case the finish coat is omitted, the decorative finish may be applied directly to the brown coat. It is also essential that, in order to avoid cracks and differential expansion, the brown coat be not richer in cementitious material than the scratch coat.

A finish coat is used where a smooth white surface is required. This coat should be free from cracks, hard enough to withstand reasonable abuse, and present a pleasing appearance. This limits its composition.

In order to avoid shrinkage cracks, the coat should be as thin as possible and be troweled at exactly the proper time. Since this coat must be applied in a very thin layer over a dry, brown coat, its plasticity is exceedingly important.

Proportions: It is important to measure all ingredients used in plaster. Although proportioning may be on a weight or volume basis, the following proportions by volume are recommended for different kinds of plaster, primarily since contractors find volume measurements more convenient.

Proportions for Scratch Coat on Lath

1 volume lime to 1 1/2 volumes sand
1 volume gypsum plaster to 2 volumes sand
1 volume portland cement to 3 volumes sand

Hair or fiber should not exceed 3 bushels per cubic yards of sand.

Proportions for Scratch Coat on Masonry and for Brown Coat

1 volume lime to 3 volumes sand
1 volume gypsum plaster to 3 volumes sand
1 volume portland cement to 3 volumes sand

If finish coat is used, hair or fiber should not exceed 1 1/2 bushels per cubic yards of sand.

Explanation of Tables: "One volume of lime" represents one volume of either lime putty or dry hydrated lime. Lime may be mixed with portland or Keene's cement in any desired proportions. Portland cement should not be mixed with either Keene's cement or gypsum plaster. The quantities of sand suggested are accepted generally as good practice, but slight variations may be necessary because of differing qualities of materials used.

For the finish coat of lime, enough calcined gypsum should be added to make the material set within the desired time. The proportions used depend upon the area to be covered and weather conditions. The amount of water used should be such as to provide the desired consistency. White sand or marble dust is sometimes used in the finish coat.

Application: The scratch coat should be thoroughly troweled to key the plaster to the backing and built up to about one-fourth inch uniform thickness. Before hardening, its surface should be "scratched" with a suitable tool making horizontal V-shaped grooves one-eighth inch deep, about one inch apart. On masonry walls, the decorative finish may be applied to the scratch coat which should be plane and true. If a finish coat is used, however, the scratch coat should be allowed to harden thoroughly before the finish coat is applied.

The brown coat should be thoroughly troweled, pushing the material into the depressions in the scratch coat. It should then be built up to the desired thickness, and rodded to produce a plane true surface, flush with the grounds. It should then be darbied to take out the irregularities left by the rod. Finally, it should be floated to take out the last of the irregularities and produce sufficient porosity to give the proper suction for the application of the finish coat. It should then be permitted to set until thoroughly hard and dry, before applying the finish coat, or any other decorative finish.

More care should be used in applying the finish coat[1] than the previous coats. As large an area as possible of each wall surface should be covered at one time in order to avoid ridges and joints, and the coat should be as thin as practicable but thick enough to completely cover the under surface. At the proper time, the coat should be troweled, applying considerable pressure, in order to prevent shrinkage cracks. Brushing the surface with water while troweling is the method generally used to obtain a smooth finish.

"Doubled-up" or "laid-on" plaster work (scratch and brown coats applied at one time) is usually not advisable. This practice is not recommended for wood lath, especially when the plaster is to be seven-eighths inch thick. It should never be applied on metal lath. Its use on masonry backings is largely a question of application. If the plaster can be made to stay in place with a true and plane surface, the work should prove satisfactory.

Exposure: Lime has a high water-carrying capacity although very little water is required for its hardening. Consequently in its drying process, a good circulation of warm dry air is necessary.

Gypsum plaster requires water in its hardening process and care should be taken to provide sufficient to prevent a "dry-out".

Portland cement requires the presence of water throughout its hardening process. For gypsum, the hardening process may be completed in a comparatively short time, whereas in the case of portland cement, the process may be extended over a period of several days. This accounts for the practice of wetting a cement plaster wall once a day until the plaster has completely hardened.

To prevent warping, wood trim should not be applied to plaster walls until they are sufficiently dry.

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[1]Other finishes are described in TIBM - 27.